LINKING BEST-VALUE PROCUREMENT WITH PROJECT PERFORMANCE OUTCOMES IN DESIGN-BID-BUILD VERTICAL CONSTRUCTION PROJECTS

By

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Submitted to the graduate degree program in Civil, Environmental and Architectural Engineering and the Graduate Faculty of The University of Kansas in partial fulfillment of the requirement for the degree of Master of Science

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Date Defended – January 28, 2019

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Date Approved – January 28, 2019

ABSTRACT

Construction is a dynamic process in which the outcomes depend on the quality of the project team; therefore, awarding the project to the best-suited contractor an important decision for owners. One method of contractor procurement is the best-value (BV) approach. When using this approach, the owner considers contractors' qualifications in addition to their proposed prices; in contrast, price is the sole criterion in traditional low-bid procurement. BV has been used extensively by owners in the past few decades, with the goal of selecting the best-suited contractor for a specific project. But little research has been conducted that justifies the use of BV procurement within the Design-Bid-Build (DBB) system. This study aimed to fill the gap in the literature by statistically identifying whether BV procurement leads to owner's benefits. Data were collected from 118 construction projects that were BV procured and D-B-B delivered. The data included the information such as the contractors' price proposals and qualifications (as assessed through technical proposals, interviews, and past performance). The data also included performance indicators such as owner satisfaction scores and cost and schedule overruns. All the projects selected for this study were public vertical projects; most were renovation projects. The data were analyzed through using descriptive statistics and inferential statistics. The results indicate that employing a BV-procured contractor can be beneficial to owners in terms of cost and schedule performance. The findings also indicate that groups of contractors that receive high scores for technical proposals and interviews also achieve better project performance. Because BV involves potentially selecting an expensive contractor compared to the lowest bidder, an attempt was made to measure the cost of the selected contractor. To measure the cost, the concept of total BV cost was developed. The results indicate that BV-selected contractors have lower overall costs than do average bidders.

ACKNOWLEDGEMENTS

There are not enough words to thank my advisor, Dr. Brian Lines, for his continual support throughout the course of this research. I would like to thank him for giving me an opportunity to learn and work with him and for showing confidence and faith in me. I would also like to recognize his efforts to lift my spirits when I was lacking confidence. I can simply say that Dr. Lines is one of the best professors I have ever met and worked with.

I would like to extend my sincere gratitude to my thesis defense committee, Dr. Dan Tran and Professor Michael Panethiere, for the time and valuable input they have given regarding my thesis. I would also like to thank them for sharing their knowledge with me during my time at the University of Kansas.

I would like to sincerely thank the Department of Civil, Environmental, and Architectural Engineering at the University of Kansas for accepting me as a student in the graduate program and for providing me with all the resources needed to successfully finish my graduate degree.

Finally, I would like to thank my mom and the love of my life, without whom this thesis would not be possible. A special thanks to my sisters, friends, and family for their love and continual support.

DEDICATION

I would like to dedicate this research to my beloved dad, who inspired me to become who I am.

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CHAPTER 1: INTRODUCTION

1.1 Background

Historically, construction contractors have been procured through low-bid methods, wherein owners exclusively consider price when selecting a contractor for project award (Kashiwagi and Savicky 2002, Yu and Wang 2012). Owners have continued to use the low-bid system due to the ease of identifying the lowest bidder, even though many owners are not satisfied with the performance of the system (Kashiwagi and Mayo 2001). Sometimes, the low-bid method has caused contractors to quote artificially low bids (Yasamis et al. 2002). For example, a contractor might submit a low bid when the contractor has a shortage of work, preferring a low-paying project rather than no business at all (Hatush and Skitmore 1997).

Owners' extensive use of low-bid procurement and their lack of knowledge about other procurement methods are perceived to be problems in the construction industry (Post 2000). Low-bid procurement can lead to poor construction performance because bidders are not inclined to fully understand the needs of the client (Luu et al. 2005, Post 2001). Many previous studies indicate that the lowest bid may not be the best bid when the final cost is taken into account (Wong et al. 2001, Kashiwagi and Mayo 2001).

An increasing number of owners are becoming aware of multicriteria procurement, in which more than price is considered when selecting a contractor (Wong et al. 2001). Owners are choosing to use these procurement approaches because of the inadequate performance of low-bid contractors, the increasing complexity of construction design, the decreasing duration of the procurement phase, increasing construction costs, and litigation. One alternative approach is best-value (BV) procurement (Kashiwagi 2003, Kashiwagi and Savicky 2002,).

1.2 BV Procurement

The construction industry has been gradually transitioning from using traditional low-bid approaches to using BV procurement methods to select contractors. BV procurement is a procurement method that considers cost qualifications-based aspects; the intent is to select the bidder that proposes the best balance between a competitive price and strong qualifications (El Warani et al. 2006).

The fundamental premise of BV procurement is that the owner can achieve a more effective and efficient construction process by considering contractor qualifications along with price during the bidding process. Yet, in many organizations that buy a large volume of construction services, the perception exists that BV may result in larger up-front costs if the lowest bidder is not selected. Further, organizations may perceive that selecting the BV contractor may not result in end-of-project savings (which would justify larger up-front expenditures). Neither of these perceptions has been empirically verified in the literature.

An owner may be willing to award a project to a non-low-bid contractor as long as the BV contractor has the potential to limit cost increases during construction (Scott et al. 2006). The ability of BV procurement to improve cost performance has not been widely examined, particularly for design-bid-build (D-B-B) vertical construction projects. Also, there is limited research on the schedule and quality performance of BV projects. Empirical research on the cost, schedule, and quality indicators in BV-procured projects is important in helping owners better assess the benefits (or lack thereof) associated with utilizing BV procurement as a replacement for traditional low-bid methods of selecting construction contractors.

1.3 Research Objectives

The main objective of this study was to determine the BV cost impact at the time of bidding and during construction, resulting in a quantification of the overall cost impact of BV procurement. Data on the procurement and performance of 118 BV construction projects were analyzed in this study. All the projects selected for the study were public-owned, vertical institutional construction projects and were delivered through the D-B-B system.

Another important objective of the study was to determine whether a statistically significant correlation exists between project performance (cost, schedule, and owner satisfaction) and the qualifications of the contractor. In addition, the performance of different contractor groups was analyzed to identify any significant differences between groups. Understanding whether any relationships exist is important because owners may be willing to pay more up front to maximize project performance.

1.4 Thesis Outline

After the research objectives were established, it was important to plan the research in order to obtain the desired results. The data collected from 118 construction projects were analyzed using descriptive and inferential analytical methods. In addition to this introductory chapter, this thesis contains the following chapters:

- Chapter 2—Literature Review: This chapters contains brief summaries of previous studies in the areas of BV procurement and general project performance. This chapter identifies criteria that owners have used in BV procurement. Project performance is discussed in terms of cost and schedule growth percentages, resulting in the identification of past trends. Also, previous studies involving renovation projects were analyzed.

- Chapter 3—Research Objectives: This chapter identifies the research needs, objectives and the research questions and hypotheses that were addressed in this study. The expected research contributions are also stated in this chapter.
- Chapter 4—Methodology: The analytical methods used in this study are described in this chapter. The chapter also presents the data collection process and definitions of the variables examined in this study.
- Chapter 5—Results: This chapter presents the important results from analyzing the data collected in the study.
- Chapter 6—Discussion: In this chapter, the analysis results and their importance are discussed.
- Chapter 7—Conclusion: This chapter provides conclusions regarding the results and summarizes the major takeaways.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Historically, construction projects have typically been procured through the low-bid selection process. Owners have begun to adopt other selection methods, such as the multicriteria approach, in order to achieve better project performance. This chapter contains a review of past studies on low-bid procurement and the evolution of BV procurement. The literature review also discusses research on project performance in terms of cost and schedule, including in BV projects and renovation projects.

2.2 Low-Bid Procurement

In the last few decades, many new procurement methods and delivery systems have been developed. Nevertheless, low-bid procurement has remained the most popular method (Kashiwagi et al. 2004). In this system, selection is based solely on the price presented in contractors' bids (Molenaar et al. 2014). Contractors develop detailed bids after carefully reviewing the complete (or nearly complete) set of plans and specifications; the goal is for the bidders to propose to construct the project for the lowest possible cost. The bid with the lowest price proposal is automatically awarded the project.

Some owners believe that low-bid procurement gives the best incentive to keep costs down (Bajari and Tadelis 2001). This selection method has been used particularly in public projects, for which the selection process must be transparent and unbiased (Falagario et al. 2012, Kashiwagi et al. 2014). According to Gransberg and Ellicot (1997), low-bid procurement simplifies bid preparation and review, and it limits the likelihood that bidders will protest the award decision because the lowest bidder is the clear winner.

The low-bid process has many drawbacks because only price-related factors are considered in contractor selection. This procurement process can lead to huge cost overruns and schedule growth (Illia 2001). Further, owners cannot balance quality and cost factors, including ease of operation, when selecting contractors through low-bid procurement (Markus 1997). In this system, the contract between the owner and contractor does not address the quality and timeliness of the construction process (Gransberg and Ellicot 1997). Achieving the lowest final cost possible becomes the major focus, potentially resulting in an extended construction duration and lower quality. The complexity and risk involved in low-bid procurement can also result in misunderstandings, reactive contractor behavior, and hostile relationships (Kashiwagi et al. 2010).

2.3 BV Procurement

Because of underperformance in low-bid projects, owners may adopt alternate procurement methods, such as BV and qualification-based selection. These methods consider price as well as nonprice factors, such as time, quality, and local content (Rankin et al. 1996; Minnesota Department of Transportation [MnDOT 2012]; Gransberg and Senadheera 1999). BV procurement is often described as a method of obtaining the highest value for the money (Schottle and Arroyo 2017). Scott et al. (2006) defined *BV* as a “procurement process where price and other key factors are considered in the evaluation and selection process to enhance the long-term performance and value of construction.” The BV approach creates a win-win scenario for the client and the contractor, maximizing the project value at the lowest possible cost and with minimal cost and schedule overruns (Kashiwagi et al. 2012).

BV procurement is advantageous to owners in various ways. For example, the system enables owners to consider the project-specific expertise of contractors, which in turn helps owners manage risks and minimize costs (Kashiwagi and Byfield 2002). Also, this method emphasizes quality, efficiency, and maximum value in terms of money and performance (Akintoye et al. 2003). The Taiwan Ministry of Justice (2009) reported that BV projects have higher contracted values than do low-bid projects. BV procurement has a potential to reduce overall cost and project duration because the contractor must develop detailed project and procurement plans in the early stages of the project (Gransberg and Ellicott 1997). Additionally, with this method, owners examine various factors that need to be considered to enrich long-term performance (Chan et al., 2004).

Gransberg and Ellicot (1997) stated that a disadvantage of BV procurement is that the process is complicated. Further, the method can increase the effort and time required to prepare a solicitation package. There is also a greater likelihood that bidders will protest the award decision and, consequently, that the contract award will be delayed.

Previous research on BV was thoroughly reviewed, with a focus on contractor evaluation criteria, multicriteria decision-making, and BV project performance. Owners have considered various contractor qualifications when using BV procurement. The qualifications were used as part of various decision-making tools to identify the most valuable contractor. The literature regarding evaluation criteria was studied to identify the most common evaluation criteria used by the owners. The literature review also included studies regarding the techniques that owners use to identify the best contractor. Finally, studies on BV project performance were analyzed to identify trends in project performance.

2.3.1 Evaluation Criteria

While procuring BV projects, owners request a variety of information from the bidders, such as regarding qualifications, technical proposals, and price proposals (Bamberger and Stark

2008). The qualifications can be objective or subjective. The rest of this section discusses key studies on the use and effectiveness of various BV evaluation criteria.

Bubshait and Al-Gobali (1996) studied criteria that were considered in the prequalification practices for semipublic and private projects in Saudi Arabia. Data were collected by examining the prequalification practices of 19 large companies and through sending a questionnaire to 202 randomly selected companies. The responses were analyzed using an impact index and rank-order techniques. The researchers concluded that the most common evaluation criteria were contractor experience, financial stability, past performance, project management capabilities, availability of management staff, and contractor project capacity. The researchers compared these results with criteria used in the United States and found that the prequalification criteria are similar in both countries.

Russell and Skibniewski (1987) identified that the characteristics of the decision-maker and the characteristics of the contractor are key factors in selecting a contractor. This study involved interviews with construction professionals, including owners, construction managers, architects, and personnel in surety companies that perform prequalification tasks. The results indicate that the following factors were considered when deciding which contractor was the best for a project: the type of company the participant worked at, projects that had been completed, current balance sheet information, projects currently under construction, the experience of key personnel, and references.

According to Gransberg and Ellicot (1997), the evaluation criteria in BV procurement can be quantifiable or nonquantifiable. The criteria can include technical excellence, management capability, financial status, personnel qualifications, relevant experience, past performance, optional features offered, proposed completion date, and organizational risk.

Hasnain and Thaheem (2016) reviewed the literature to identify evaluation criteria used in BV procurement. Based on the literature, the researches presented a framework containing eight important factors: cost, risk, performance, quality control, health and safety, project control, delays, and current workload. Hasnain and Thaheem also proposed how ranking the factors can influence the selection of a contractor.

According to Scott et al. (2006), important BV parameters include cost, time, qualifications, quality, and design alternatives. Ojiako et al. (2014) conducted a study to explore BV procurement in public building construction in Korea. The investigators sent a questionnaire to six experts in a public-sector stakeholder group. The results indicate that important factors include serviceability, safety, comfort, environmental impact, economic feasibility, and artistry. Based on using an analytic process to weight the criteria, the researchers concluded that using these criteria leads to the best results when procuring contractors for public construction projects.

Russell et al. (1992) analyzed 10 questionnaire items sent to public owners, private owners, and construction managers. The results indicate that the major factors in selecting a contractor are financial stability, availability of key personnel, relevant experience, and past performance.

Doloi (2009) sent a questionnaire to 155 project managers, contract administrators, design managers, and clients in Australia to determine the influence of the attributes on the decision-making process. Through analyzing the responses, the investigator identified 43 influential attributes to use in prequalifying contractors. After performing factor analysis on these attributes, Doloi determined that the most significant are the soundness of the business and the workforce, planning and control, quality management, past performance, risk management, organizational capability, and commitment. After preforming multiple linear regression, the author concluded that technical expertise, past success, time in business, work methods, and working capital have a significant relationship with contractors' performance in terms of time, cost, and quality.

BV elements can be objective or subjective, according to Gransberg and Shane (2015). The researchers reported that objective elements include contractors' project experience, timely completion of the projects, compliance with material specifications, workmanship, safety record, and accuracy of submittals. Subjective elements include subcontractor management, training and employee development programs, corporate commitment to achieving customer satisfaction, and clients. In this research 36 construction projects for 26 public transportation agencies in 14 states were analyzed. The researchers concluded that nonprice factors are more important than price factors and should therefore carry greater weight in evaluation plans. Also, as an agency's experience increases, the weight of the price factor decreases.

The MnDOT used design-build (D-B) project delivery in conjunction with a two-step BV procurement method in the construction of an additional lane on either side of a well-traveled arterial highway (Shane et al. 2006). MnDOT required that bidders provide information regarding the following: organization and experience, key personnel, project understanding, project approach, project management, and legal and financial qualifications. The MnDOT completed 30% of the design and then required the selected contractor to finish the design and to construct the road. During the bidding phase, the MnDOT issued a request for qualifications in the first step and a request for proposals (RFPs) in the second step.

According to Palaneeswaran and Kumaraswamy (2000), a contractor should be evaluated and selected based on its capabilities, relevant experience, and qualifications, not merely on price. These researchers focused on developing a model for contractor prequalification and bid evaluation in D-B projects. The researchers identified the following criteria for selecting contractors: understanding of the project, design and construction approach, delivery of work, management of the services, qualifications and experience, and costs. The researchers proposed an effective model to procure contractors for D-B projects without analyzing the performance of projects procured using this method.

Alsugair (1999) conducted interviews with experts from private companies, public establishments, and banks to identify evaluation criteria. The experts discussed 36 factors, which Alsugair grouped into nine categories: financial evaluation of bid; understanding of bid, project location, contractor qualifications, completeness of bid document, relevant experience and reputation of the contractor, the contractor's organization, submission of alternative offers, and foreign companies. The researcher developed a framework for selecting contractors; in this framework, each criterion is assigned a weight according to importance. The study did not examine the overall project performance of the selected contractors.

Gransberg and Molenaar (2004) analyzed 78 RFPs to classify current approaches to evaluating quality in public D-B construction. The selected RFPs came from public vertical and horizontal projects, such as residential, commercial, industrial, highway, bridge, rail/light, and rail/transit. Six general approaches to examining D-B quality requirements were identified—namely, by examining qualifications, programs, specified programs, performance criteria, specifications, and warranty.

The benefits that federal owners seek when using the D-B process were identified by Gransberg and Barton (2007), who analyzed 110 RFPs. The RFPs were collected from 11 federal agencies, and the projects regarded housing, schools, office buildings, renovation, technical facilities, technical systems, and indefinite delivery-indefinite quantity work. In this study, the evaluation criteria were organized into the following categories: price, technical, qualifications, schedule, and project management. The results were compared to the findings of a 1996 study, with the goal of identifying any correlations between owner attitudes and selection criteria. Gransberg and Barton concluded that a typical federal agency prefers to select a well-qualified D-B team with a low bid.

2.3.2 Multicriteria Decision-Making

Selecting the right contractor for a project is a crucial decision for a project owner (Singh and Tiong 2006). In recent years, increased project complexity, higher performance, and financial and safety requirements have led to the use of multicriteria decision-making methods (Cristobal 2012). Multicriteria decision-making involves making decisions through considering multiple, usually conflicting, criteria (Xu and Yang 2001). According to Chaphalkar and Shirke (2013), research on multicriteria decision-making is an advanced field of operations research that is devoted to the development and implementation of tools and methodologies to aid in solving complex problems involving multiple criteria and goals. In project procurement, multicriteria decision-making involves considering various contractor qualifications and other criteria to effectively determine the best contractor for a project. Researchers have analyzed various multicriteria decision-making models in contractor selection; some of these models are summarized in this section.

In recent years, some owners have shifted from using low-bid procurement to multicriteria procurement (Wong et al. 2010). Two multicriteria decision-making methods—TOPSIS (technique for order preference by similarity to ideal solution) and VIKOR (*vlsekriterijumska optimizacija I kompromisno resenje*) were studied by Cristobal (2012). The researcher found that these methods are effective tools for selecting contractors based on multiple factors and the owner’s expectations. When both these methods were employed to select a contractor for a road construction project in Spain in 2002, the results were the same regarding which bidder received the highest ranking. Cristobal concluded that being highest ranked according to the TOPSIS method implies that the contractor is the best in terms of ranking index, whereas being highest ranked according to the VIKOR method implies that the contractor is the closest to having the ideal solution.

Balubaid and Alamoudi (2015) used the analytical hierarchy process to determine the relative importance of the following evaluation criteria: financial capability, past performance, relevant experience, resources, current workload, and safety performance. Interviews and meetings were held with senior project engineers, project managers, contract advisors, and project controllers to rank the criteria according to their importance. The collected data were analyzed using the analytical hierarchy process, and the findings indicate that the process can be used in contractor procurement to determine crucial criteria to use when selecting a contractor.

In another study, Nieto-Morote and Ruz-Vila (2012) used the fuzzy set theory to evaluate the selection criteria of technical capacity, relevant experience, management capability, financial stability, past performance, past relationships, reputation, and occupational health and safety. Fuzzy set theory uses of an algorithm to address the inconsistencies in the fuzzy preference relation when pairwise comparisons are used. Fuzzy set theory can also be used to linguistically assess the performance of contractors based on qualitative and quantitative criteria. After developing a model, Nieto-Morote and Ruz-Villa applied it to a rehabilitation project for a building at the Technical University of Cartagena. The researchers concluded that fuzzy set theory is an adequate tool to use with imprecise and uncertain problems; in particular, these problems can be addressed through using variables with values that are words or sentences in natural language, rather than values that are numbers.

2.3.3 Performance of BV Procured Projects

Several studies have reported the benefits of BV procurement to owners and contractors. Researchers have quantified the advantages of BV procurement in terms of cost and schedule. This section summarizes the studies that quantify the benefits of BV selection.

Hilger (2009) reported that MnDOT successfully developed and used BV procurement for a D-B project (MnROC 52) in Rochester, Minnesota. The author's aim was to study BV selection in the state after the collapse of the I-35 bridge. To do so, Hilger examined the method's use in public agencies such as the Minnesota Department of Administration, the MnDOT, the University of Minnesota Capital Planning and Project Management Group, and the South Washington County School District, as well as agencies in Roseville, Eagan, and other cities and in counties. The MnROC 52 project was successful in that the contractor completed the project two years earlier than anticipated. The contractor saved $36 million in road-user costs, which were set at $50,000 per day at the time of project award. In 2007, BV was also used to procure a contractor to reconstruct the I-35 bridge. The bridge was successfully built in a very short time, which resulted in a great benefit to the contractor. In contrast, a similar reconstruction project (for Wakota Bridge) was not successful. A different procurement method was used, and the project was delivered using traditional D-B-B. Major design errors resulted in the project's failure. Hilger concluded that owners are highly satisfied with BV-procured contractors. The study only examined the performance of BV-procured projects in Minnesota, without considering the qualifications of contractors.

Migliaccio et al. (2010) compared the performance of projects procured using the low-bid, BV, and adjusted-bid methods. The data in this study consisted of procurement and performance information for 146 transportation projects delivered using the D-B method. The aim of the research was to determine the differences in project performance in terms of cost and schedule growth based on the length of the procurement process. Using statistical methods, the researchers found a strong linear correlation between schedule growth and procurement duration. In the research, BV-procured projects experienced cost increases of −1.5% and schedule growth of 12%, on average, whereas low-bid projects had average cost increases and schedule growth of 3.1% and 11%, respectively.

Contractors receive more benefits from BV projects than from low-bid projects, according to a study by Sullivan and Guo (2009). The researchers developed a questionnaire regarding 13 cash flow risks, with the goal of studying the effects of BV on project cash-flow risks and contractor profitability. Survey responses were obtained from 26 contractors who built BV-selected projects (11%) and low-bid-selected projects (44%) projects, along with prequalified and negotiated bids, in Arizona, Massachusetts, Minnesota, and Texas. The projects delivered by the contractors used D-B-B, D-B, CMAR (construction manager at risk), and other delivery systems, with the majority being D-B-B (63%). The survey results show that BV procurement has a greater effect on cash-flow risks and contractors' profit in BV projects (8%) than in low-bid projects (2%).

El Wardani et al. (2006) compared the performance of sole-source, qualifications-based, BV, and low-bid procured D-B projects. Survey data were collected regarding 76 D-B projects in the United States. The goal of this research was to determine whether correlations exist between (a) the procurement method used in D-B projects and (b) the performance metrics of cost, time, and quality. The researchers concluded that performance was better in projects that involved qualifications-based procurement than in projects with other procurement methods. The cost growth in the BV-procured projects was 2.5%, whereas the cost growth in the low-bid projects was 7.3%. The schedule growth was 1.0% for BV projects, compared to 14.8% for BV low-bid projects.

2.4 Overall Construction-Project Performance

Construction projects have experienced a wide range of performance outcomes related to cost, schedule, and quality. Researchers have quantified project performance in various types of project. This literature review focused on performance data in D-B-B projects and projects in the public, vertical institutional sector.

Pocock et al. (1996) considered a number of contract modifications to cost and schedule as indicators of project performance. Cost and schedule are the most common project-performance indicators (Francom et al. 2016). Many researchers have also considered quality as a project-performance metric (El Wardani et al. 2006, Migliaccio et al. 2010; Bogus et al. 2013).

Kochar and Sanvido (1998) collected performance data on 351 building projects; 33% of the projects were D-B-B, 44% were D-B; and 23% were CMAR. The investigators found that the average cost growth of projects that were delivered through the D-B-B method was 9%, and the schedule growth was around 11 %. In another study, Hale et al. (2011) collected and analyzed data on 39 D-B-B projects and 38 D-B projects for the US Navy Bachelor Enlisted Quarters. The mean cost growth of D-B-B projects was around 4%, and the mean schedule growth of those projects was around 15%.

Data from 25 public-sector projects were analyzed by Pocock et al. (1996) to examine the relationship between project interaction and project performance. The average cost growth of traditionally delivered projects was 12.9%, and these projects had a schedule growth of 41.2%. In research by Col Debella and Ries (2006), the cost growth was 4.5% and the schedule growth was 1.3%. The researchers collected data regarding projects in public school districts in Pennsylvania, Ohio, New Jersey, Massachusetts, and Virginia.

Ibbs et al. (2003) analyzed 67 global projects to compare D-B-B, D-B, and other project delivery systems regarding the magnitude and frequency of cost and schedule changes. The average cost growth of D-B-B projects was −0.4%, whereas the average schedule growth was 8.4%. Allen (2001) compared the cost, schedule, and quality indicators of 110 military construction projects delivered through D-B and D-B-B. The results show that the horizontal construction projects delivered through the D-B-B method had a cost growth of 24.6% and a schedule growth of 58%. Vertical projects delivered through the same method experienced a cost growth of 17.1% and a schedule growth of 30%.

In another study, Minchin et al. (2013) analyzed data from 60 Florida Department of Transportation projects; 30 were D-B-B, and the other 30 were D-B. The average cost growth was 20.4%, and the average schedule growth was 23.0% for projects that were delivered using the D-B-B method. Uhlik and Eller (1999) analyzed the performance of eight military medical construction projects, with the goal of identifying the advantages of using alternative project delivery methods instead of the traditional D-B-B method. The researchers found that the average cost overrun was 12.93%.

2.5 Performance in Renovation Projects

Between 1992 and 2007, the expenditure on renovation projects increased from $20 billion to $120 billion in commercial and institutional sectors. Typically, it is more economically feasible for an owner to renovate a structure than to replace it (Singh et al. 2014). There is a need to understand the performance of renovation projects because their importance has been increasing rapidly.

Associates from 10 construction companies were interviewed by Singh et al. (2014) to identify production management practices in renovation projects. The investigators concluded that despite the uncertainty involved in renovation projects, there are no differences in the performance assessment methods for new and renovation construction projects.

McKim et al. (2000) compared the performance of new and renovation projects performance. The researchers used a questionnaire to obtain data on 25 reconstruction and 15 new construction projects, after which the researchers interviewed project participants. The findings indicate that new construction projects have better cost and schedule performance than do reconstruction projects.

CHAPTER 3: RESEARCH OBJECTIVES

3.1 Introduction

This chapter describes the point of departure from the existing literature, provides the study's research objectives and research question, presents corresponding hypothesis statements, and describes the expected contribution of this research. To summarize the point of departure, the traditional D-B-B delivery system has historically been associated with low-bid procurement, wherein owners use price as their sole evaluation criterion and award projects to the lowest responsible bidder. The use of alternative procurement methods, such as BV, has become increasingly common in the construction industry. Although BV procurement of construction services is most common in projects with alternative delivery methods, such as D-B and CMAR, BV procurement is also being be used in D-B-B projects. Because this trend is relatively new, little research has explicitly focused on the application of BV procurement methods in D-B-B projects.

This study aimed to address this gap by collecting data on D-B-B projects that were procured through the BV method. The data were then analyzed to identify whether a relationship existed between BV procurement and contractor performance during the project's construction phase.

Three research objectives and one question were developed related to BV-procured D-B-B projects. The first objective regarded the cost implications of BV for owners during the procurement phase. The second objective concerned performance indicators during the construction phase. The third objective regarded the total cost implications for owners of using the BV procurement method in D-B-B projects. The research question involved examining the relationship between the qualifications that contractors demonstrated during the procurement phase and the contractors' performance during the construction phase. For the research question, this study hypothesized that selecting contractors with greater qualifications would result in performance improvements during the construction phase.

3.2 Point of Departure

This research was conducted because of the limited number of studies analyzing the construction projects are procured using the BV method and are delivered using D-B-B. Most of the previous research on BV procurement was focused on alternate project delivery methods, such as D-B and CMAR. In these studies, the projects' performance outcomes were rarely considered in relation to the procurement phase. Further, most of the research on BV procurement examined horizontal projects, such as highways, rather than on vertical projects, such as buildings. Also, renovation construction has not been explored as much as new construction has.

Various procurement methods and delivery systems have been adopted and adapted to increase the effectiveness of the construction process. However, due to constraints such as government regulations, delivery methods such as D-B are used infrequently in some states; public owners have been forced to use D-B-B to deliver most of their projects, regardless of the procurement method used. It is important to analyze BV-procured, D-B-B-delivered projects in order to identify their performance, because this type of project could benefit public owners that must use D-B-B delivery. However, few studies have analyzed BV and D-B-B together. Also, there are minimal studies on vertical projects using BV procurement and D-B-B delivery.

Previous research has typically examined preconstruction procurement phases and project performance during the construction phase separately. It is important for owners to understand the correlation between procurement method and project performance. Some researchers have quantified the relationships between procurement or delivery methods and performance. But few studies have examined both procurement methods and delivery methods in relation to project performance. This gap was addressed in the current study.

This study compared BV procured projects with low-bid projects in terms of overall cost and schedule. With BV procurement, the owner considers contractor qualifications in addition to financial proposals, with the goal of improving project performance by minimized cost overruns and schedule growth. For instance, a contractor with better qualifications may bid a higher price, but the owner would expect better construction execution than the lowest bidder would provide. The awarded contractor has to outperform the lowest bidder in terms of cost and schedule management. This idea has not been analyzed in previous quantitative studies. This study attempts to address this gap in the literature by comparing BV-procured projects with low-bid projects.

3.3 Research Objectives

The research objectives of this study can be summarized as follows.

- Research Objective 1: At the time of bid submission, what are the cost implications of BV procurement compared with low-bid procurement? In other words, how much more expensive is BV procurement than the lowest bid?
- Research Objective 2: At project completion, what is the overall performance of BV-procured contractors in terms of cost, schedule, and owner satisfaction?
- Research Objective 3: What is the total cost of BV-procured projects (BV premium plus cost growth) compared with an idealized low-bid project that has no cost growth?

3.4 Research Question

The key research question for this study is as follows.

- Research Question 1: In BV-procured projects, what is the relationship between the awarded contractor's qualifications and performance during the construction phase?

3.5 Hypothesis Statements

Based on the research design and nature of data collection, results for research objectives 1, 2, and 3 were investigated using descriptive analytical methods; therefore, no formal hypothesis statements were established for the question. For research question 1, three hypothesis statements were developed and then tested using inferential statistical methods. Each hypothesis was divided into three statements to accurately describe the hypothesis test in relation to the three dependent variables regarding project performance.

3.5.1 Hypothesis 1

- *Hypothesis 1a (H1.a)*: Awarded contractors with higher technical-proposal evaluation scores achieve lower cost growth than do awarded contractors with lower technical-proposal evaluation scores.
- *Hypothesis 1b (H1.b)*: Awarded contractors with higher technical-proposal evaluation scores achieve lower schedule growth than do awarded contractors with lower technical-proposal evaluation scores.
- *Hypothesis 1c (H1.c)*: Awarded contractors with higher technical-proposal evaluation scores achieve higher owner satisfaction than do awarded contractors with lower technical-proposal evaluation scores.

3.5.2 Hypothesis 2

- *Hypothesis 2a (H2.a)*: Awarded contractors with higher past-performance evaluation scores achieve lower cost growth than do awarded contractors with lower past-performance evaluation scores.
- *Hypothesis 2b (H2.b)*: Awarded contractors with higher past-performance evaluation scores achieve lower schedule growth than do awarded contractors with lower past-performance evaluation scores.
- *Hypothesis 2c (H2.c)*: Awarded contractors with higher past-performance evaluation scores achieve higher owner satisfaction than do awarded contractors with lower past-performance evaluation scores.

3.5.3 Hypothesis 3

- *Hypothesis 3a (H3.a)*: Awarded contractors with higher interview-evaluation scores achieve lower cost growth than do awarded contractors with lower interview-evaluation scores.
- *Hypothesis 3b (H3.b)*: Awarded contractors with higher interview-evaluation scores achieve lower schedule growth than do awarded contractors with lower interview-evaluation scores.
- *Hypothesis 3c (H3.c)*: Awarded contractors with higher interview evaluation scores achieve higher owner satisfaction than do awarded contractors with lower interview evaluation scores.

3.6 Expected Research Contributions

The research was expected to make several contributions. First, the study quantified the performance of BV-procured contracts both at the time of contract award and at the time of project completion. Examining these two points in the construction project lifecycle enabled the researcher to link BV-procurement decisions with end-of-project cost and schedule performance. The study also quantified the amount beyond the lowest-bid alternative that was incurred at the time of contract award. Consequently, the study identified the upfront cost implications of selecting contractors with greater expertise. The study also identified the overall cost savings realized by using BV procurement instead of low-bid procurement.

Further, this study related the qualifications of awarded contractors (as assessed by owner evaluation scores during the procurement phase) with the contractor's construction-phase performance. This information can aid industry practitioners in understanding which qualifications-based evaluation criteria are indicators of construction-phase performance. As a result, owners will be better able to improve their BV-procurement procedures, such as by prioritizing the weights of qualifications-based evaluation criteria that are linked with project performance improvements.

CHAPTER 4: METHODOLOGY

4.1 Introduction

The methodology that was adopted for this research relates procurement methods and performance in D-B-B projects. Data from 541 construction projects completed in the last ten years were collected for this study. Because the scope of this research was limited to BV-procured, D-B-B projects, the data set was narrowed to 118 relevant projects. The data included project documents, such as evaluation matrices, project records, and project closeout reports. Data included contractor qualifications that were considered during procurement, as well as the roles of project participants in construction performance. This chapter provides detailed information about the research methodology and data collection process for the study.

4.2 Data Collection

Various project documents were collected for this study. The documents included RFPs, matrices used to evaluate potential contractors, records of all the change orders and their impacts, and project closeout reports regarding owners' satisfaction. The data came from 541 projects completed over the past decade for public owners in the United States and Canada.

The overall data set was filtered so that only projects that were BV procured and D-B-B delivered were included in the study. Data were excluded if they regarded low-bid, D-B, or CMAR projects. Further, horizontal projects were also removed from the data set. Finally, only public-owned institutional projects were included in the final data set. Figure 4.1 shows the locations of the projects included in the study.

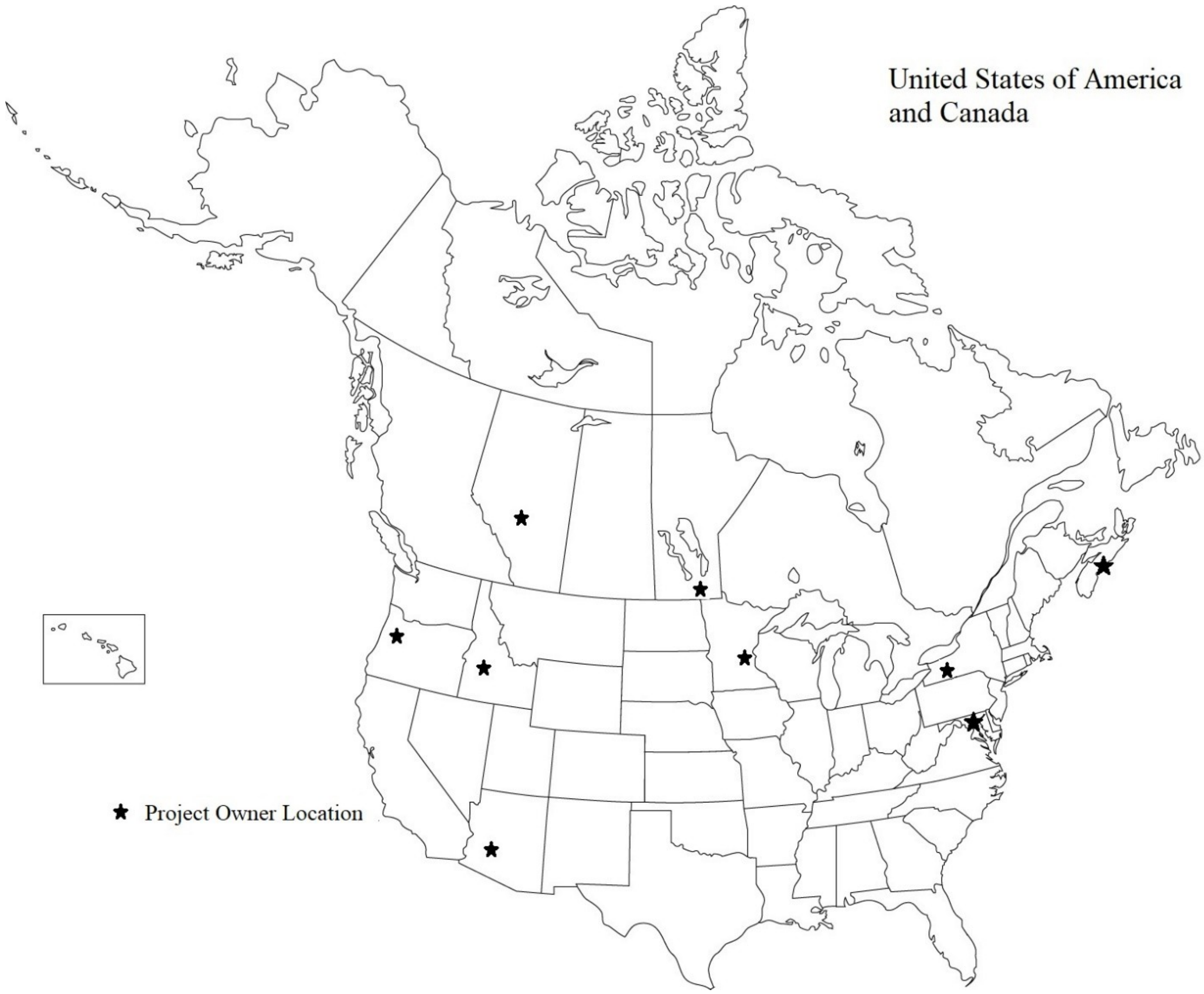

Figure 4.1: Location of Participating Owner Organizations

This filtering process resulted in 118 projects being included in the study. The final dataset included projects for public owners such as universities, schools, state departments of transportation, city governments, county governments, the federal government, and public utilities. Table 4.1 shows the number of projects from each type of owner.

Table 4.1: Classification of Projects by Type of Public Institutional Owner Organization

Type	Owners		Projects	
	#	%	#	%
Public university	3	23.1	70	59.3
Public school	2	15.4	32	27.1
State department of transportation	2	15.4	2	1.7
City council	1	7.7	6	5.1
Federal government	1	7.7	1	0.8
County	2	15.4	5	4.2
Public utility	2	15.4	2	1.7
Total	13		118	

The projects varied in terms of the category of work. As shown in Table 4.2, the majority of projects were general construction. The remaining categories included mechanical, electrical, and specialty construction (e.g., roofing and masonry). The projects were conducted in facilities with similar functional uses, such as classrooms, laboratories, and office spaces. As shown in Figure 4.2, 79.7 of the projects were renovation construction. Only 20.3% of the projects were new construction.

Table 4.2: Classification of Projects according to Prime Contractor Scope

Scope	# projects	% projects
General contractor	71	60.17
Mechanical contractor	20	16.95
Electrical contractor	19	16.10
Other specialty contractor	8	6.78

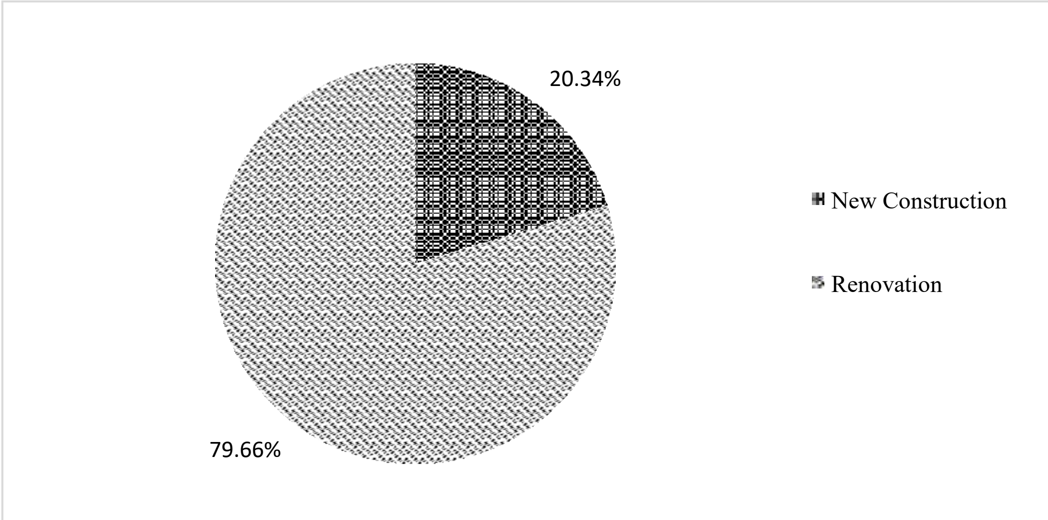

Figure 4.2: Classification of Projects According to Type of Construction

Table 4.3 summarizes the characteristics of the 118 projects. The total awarded cost was $164,643,990. The mean awarded cost and standard deviation were $1,395,288 and $3,546,658, respectively. The projects had a total awarded schedule of 17,356 days. The mean awarded schedule was 147 days, with a standard deviation of 113 days.

Table 4.3: Summary of Project Characteristics

Category	#
Total number of projects	118
Cost characteristics	
Total awarded cost	$164,643,990
Mean awarded cost	$1,395,288
Median awarded cost	$394,650
Std. dev. of awarded cost	$3,546,658
Maximum awarded cost	$25,987,230
Minimum awarded cost	$22,500
Schedule characteristics	
Total awarded schedule	17,356 days
Mean awarded schedule	147 days
Median awarded schedule	116 days
Std. dev. of awarded schedule	113 days
Maximum awarded schedule	519 days
Minimum awarded schedule	21 days

4.3 BV Procurement Procedures within the Dataset

The data set used in this study was designed based on the evaluation matrices the project owners used to evaluate potential contractors. The owners' matrices were similar in nature; there were subtle variations based on the nature of the projects. The most commonly used evaluation criteria were used as variables for analysis in this study.

4.3.1 Evaluation Criteria

In this study, the term *evaluation criteria* refers to the criteria that owners used to procure contractors through the BV method. The criteria that are included in the evaluation matrix depend on the project needs (Beard et al. 2001; Tenah 2001). At the start of the selection process, the owner identifies criteria and their relative importance; the owner then publishes this information in the Request for Qualifications and the RFP (Bamberger and Stark 2008).

Several criteria were used to evaluate contractors in the projects examined in this study. Aside from the financial proposal, the most common qualification criteria were technical proposals, past performance, interviews, and schedule proposals. Not all of these criteria were used in every project. Criteria considered in fewer projects included a seat sample for a theatre seating renovation project, a wall systems proposal for a demountable wall systems project, and a roof warranty for a roofing project. Only the most frequently used criteria were selected as variables to analyze in this study.

4.3.2 Evaluation Weights

In the evaluation matrices, each evaluation criterion was assigned a weight, according to the criterion's importance compared to other criteria in the evaluation matrix. The weight of each criterion is discussed in the following section.

4.4 Independent Variables

The most commonly used criteria in evaluation matrices were selected as independent variables for this study. They regard the awarded contractors' cost and schedule proposals, as well as the contractors' qualifications scores. Specifically, the independent variables are financial proposal, technical proposal, past performance, interviews, and schedule proposal.

4.4.1 Financial Proposal

The financial proposal is the total dollar amount the contractor proposed for the project at the time of bidding. This variable was one of the most frequently considered selection criteria. When responding to owners' RFPs, contractors include the amount they must be paid if they are awarded the project. A contractor calculates this amount by estimating direct project costs and including other compensations and fees that are necessary to finish the project. Cost bids were converted into a percentage-based evaluation score measured on a scale of 0%–100%. The owner's evaluation committee assigned a 100% evaluation score to the lowest-bidding contractor. Other contractors received linearly prorated scores based on the percent differential between their bids and the lowest bid.

4.4.2 Technical Proposal

Contractors were required to submit technical proposals explaining their project management plans based on the scope indicated in the project's construction drawings and specifications. Contractors were also asked to provide initial risk assessments, identifying factors that might cause deviations in the budget, schedule, or quality during the construction phase. After identifying potential risks, the contractors recommended how to mitigate each risk. Finally, the contractors provided value engineering feedback that might benefit the project. The owner's evaluation committee assigned each contractor's technical proposal an evaluation score of 0%–

100%. The technical proposal score for each awarded contractor was used as the independent variable for Hypothesis 1.

4.4.3 Past Performance

The past performance of a contractor is a key indicator of future performance (Steyaert 1997). As part of the RFP, each contractor was asked to provide information about the contractor team's previous project performance. The contractor team usually includes the prime/general contractor and any subcontractors. At the end of each project, the owner rates the performance of the prime contractor and any subcontractors, usually on a scale of 0–100%, with *100%* meaning "excellent." Contractors may use these ratings as a past-performance index when bidding on new projects. For Hypothesis 2, past performance score of each awarded contractor was used as independent variable.

4.4.4 Interviews

The majority of projects included interviews as an evaluation criterion. The interview criterion was designed to evaluate each contractor's project team members. The team members interviewed most commonly included the project manager, site superintendent, and lead members of critical subcontract teams (e.g., lead mechanical contractor or lead electrical contractor). The owner's evaluation committee assigned each contractor's project team a score of 0–100%. The interview evaluation scores for awarded contractors were used as the independent variable for Hypothesis 3.

4.4.5 Schedule Proposal

Some owners asked for contractors' proposed schedules. Specifically, the contractors were asked to identify the number of days required to finish the project. These days were assigned scores for ease of comparing the contractors. For each project, the contractor that proposed the fewest number of days was given a score of 100%, and all competitors received a linearly prorated score based on the percent differential from the shortest proposed schedule duration.

4.4.6 Evaluation Matrices

The owners altered evaluation matrices according to project needs. The evaluation criteria were given different weightings based on importance. The frequency with which criteria were included in evaluation matrices is summarized in Table 4.4.

Table 4.4: Frequency of Criteria Being Used in Evaluation Matrices

	Financial proposal	Technical proposal	Past performance	Interviews	Schedule	Other
Frequency	100.00%	100.00%	99.15%	55.08%	64.41%	45.76%

Table 4.5 shows descriptive statistics regarding the criteria in the evaluation matrices. Owners assigned the financial proposal a weight of 24.85%, on average. It had a maximum weight of 39.68% and a minimum weight of 10.00%. The technical proposal had the highest average weight (mean = 34.12%) among all the evaluation criteria, with a maximum weight of 45.00% and a minimum weight of 3.41%. Interviews were used 55.08% of time, as shown in Table 4.4, but had an average weight of 29.04%. Infrequently used project-specific criteria were given a weighting of 9.53% on average, with a maximum of 30.00% and a minimum of 0.77%.

Table 4.5: Weights of the Evaluation Criteria in Evaluation Matrices

	Financial proposal	Technical proposal	Past performance	Interview	Schedule	Other
Mean	24.85%	34.12%	15.39%	29.04%	8.40%	9.53%
Median	25.00%	35.00%	15.00%	30.00%	7.07%	10.00%
Mode	20.00%	35.00%	5.00%	30.00%	5.00%	10.00%
Maximum	39.68%	47.63%	45.00%	40.00%	20.04%	30.00%
Minimum	10.00%	10.00%	3.41%	10.00%	2.50%	0.77%
Std. dev.	4.95%	6.51%	9.69%	5.98%	4.05%	3.99%

4.5 Construction Phase Performance Indicators

For any construction project, the overall performance can be summarized by looking at the project performance indicators. Because one of the main objectives of this study was to relate procurement to construction performance, the study involved identifying performance indicators. For each project in the dataset, the researchers had access to the complete weekly project records kept by the construction team. These project records were called Weekly Risk Reports (WRR), and included data on all cost and schedule deviations encountered during the project. Additionally, the closeout reports were collected from each project, which identified the final project cost and schedule duration. The root cause source of each change order was tracked within this documentation, such that an accurate record of how each cost and schedule impact was realized. For each project, the owner's project manager and the contractor's project manager each mutually agreed on the accuracy of the WRR and closeout report documentation for the project.

Similar to numerous previous research, this study identified cost and schedule performance as the key project performance indicators. In this study, cost performance was measured in terms of cost overruns. Each project's final WRR included total unexpected cost increases due to the risks involved. Further, risks were classified depending on their root cause.

In these projects, the root causes of the risks were important project participants—namely, the owner, contractor, and designer. Hence, risks were categorized under four major root causes: owner, contractor, designer, and unforeseen factors. The final WRR included the total dollar increase as well as the dollar increase due to the four categories of risks. Similarly, the final WRR identified the total number of days the project was delayed due to each category of risk. This information was used to measure a project's schedule performance.

In addition to measuring cost and schedule performance, this study also measured contractor performance, in terms of owner satisfaction. For most of the projects, the owner rated the contractor in the project closeout report after the construction was completed. The owner rated contractor performance in terms of cost, schedule, quality, professionalism, responsiveness, risks, rules, and satisfaction. The average of the above satisfaction rates was adopted for analysis in this study.

4.6 Dependent Variables

In this research, the measures of project performance were dependent variables. These measures included the cost and schedule deviations tracked by the owner during the construction phase, as well as the satisfaction ratings the owners assigned at the end of construction.

4.6.1 Cost Growth

A project is said to have a cost growth if the final cost exceeds the awarded cost. The cost growth is the difference between the final cost and the awarded cost. For this study, cost growth was calculated as a percentage, using the formula shown in Equation 1.

$$\text{Cost Growth}\ (\%) = \frac{\text{Final Cost of the Project}\ (\$) - \text{Awarded Cost}\ (\$)}{\text{Awarded Cost}\ (\$)} X\ 100\ \%$$

Equation (1)

4.6.2 Schedule Growth

A schedule growth is calculated by determining the number of days that a project exceeded the awarded schedule (days). These delays were converted to percentages for this study, using the formula in Equation 2.

$$\text{Schedule growth } (\%) = \frac{\text{Final Duration of the Project (days)} - \text{Awarded Schedule (days)}}{\text{Awarded Schedule (days)}} X\ 100\ \%$$

Equation (2)

As discussed earlier, the causes of these cost overruns and schedule growth were categorized according to their root causes. Table 4.6 shows the average performance of the projects, categorized by risk type.

Table 4.6: Average Cost and Schedule Performance

Category	%
Cost performance	
Total cost growth	9.70%
Owner-caused cost increases	6.42%
Designer-caused cost increases	2.15%
Contractor-caused cost increases	0.02%
Unforeseen cost increases	1.10%
Schedule performance	
Total schedule growth	36.53%
Owner-caused schedule growth	25.42%
Designer-caused schedule growth	5.09%
Contractor-caused schedule growth	1.92%
Unforeseen schedule growth	4.14%

4.6.3 Owner Satisfaction Rate

At the end of each project, the owner rated the contractors on a scale of 0%–100%. One limitation of the study is that only 84 projects (71.2%) included owner satisfaction ratings.

4.7 BV Premium

The term *BV premium* was devised to refer to the total cost of BV procurement. The BV premium is calculated by determining the difference between the awarded cost and lowest bid submitted at the time of project award. A percentage is calculated through using the formula in Equation 3. The BV premium is 0 for a project in which the lowest bidder is awarded the project.

$$BBeeCCCC - VVFFFFeeee\ PPGGeePPFFeePP\ (\%) = \frac{AAGGFFGGAAeeAA\ CCCCCCCC\ (\$) - LLCCGG\ BBFFAA\ (\$)}{LLCCGG\ BBFFAA\ (\$)}\ XX\ 100$$

Equation (3)

4.7.1 Total BV Cost

The sum of the BV premium and cost growth is termed *total BV cost*. Cost growth is included in the total BV cost because owners would expect no cost impacts during construction because the owners are paying extra money upfront through using BV procurement. The total BV cost would be 0 in an ideal project, in which the lowest bidder is selected and no cost growth occurs during the project. The total BV cost can be compared with the cost growth of the low-bid alternative to identify any potential cost savings for the owner (see Figure 4.3). The total BV cost is calculated using the formula in Equation 4.

$$\text{Total Best} - \text{Value Cost } (\%) = \frac{\text{Best} - \text{Value Premium } (\$) + \text{Cost Growth } (\$)}{\text{Awarded Cost } (\$)} \; X \; 100$$

Equation (4)

Where

$$\text{Cost Growth } (\$) = \text{Final Cost of the Project } (\$) - \text{Awarded Cost } (\$)$$

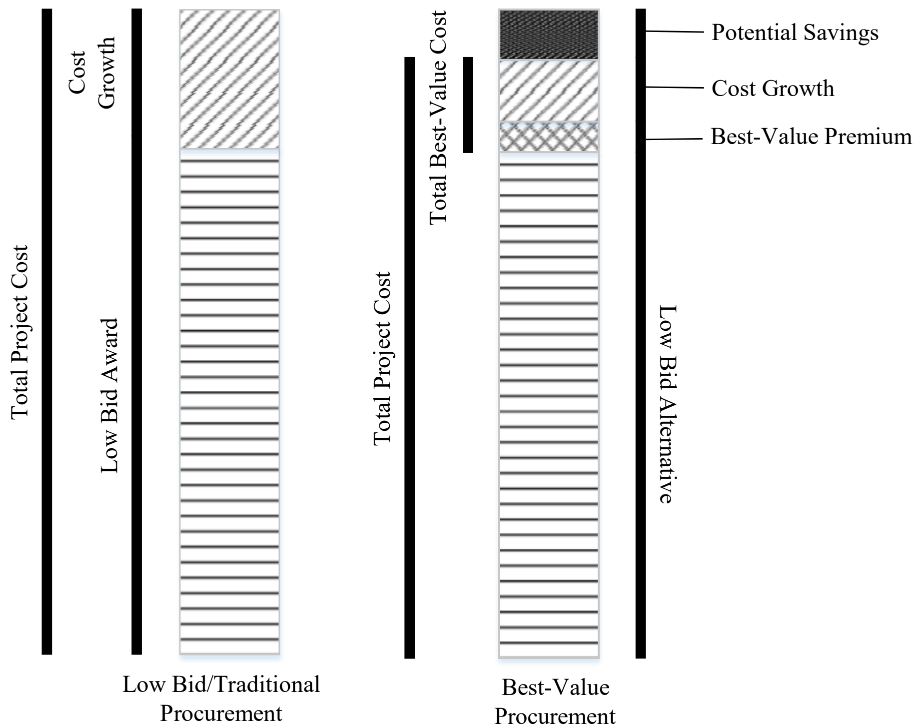

Figure 4.3: Conceptual Comparison between Low-Bid and BV Procurement Methods

4.8 Method of Analysis

Based on the research objectives, the data collected from 118 construction projects were analyzed using descriptive and inferential statistical methods.

4.8.1 Descriptive Analysis

Descriptive analysis can be used to summarize a data set and describe its characteristics in detail. In this study, descriptive statistics were used to calculate the mean, median, mode, maximum, minimum, and standard deviation for each variable.

To address Research Objective 1, descriptive statistics were used to determine the cost implications of a BV-awarded contractor. As part of this analysis, the data were divided into two categories: (a) projects in which the BV premium was 0 (because the project was awarded to the lowest bidder) and (b) projects in which the BV premium was not 0. Descriptive statistics were also used to answer Research Objective 2 and 3. The overall performance of projects was analyzed descriptively to answer Research Objective 2. To answer Research Objective 3, project procurement data and project performance data were analyzed in conjunction.

4.8.2 Inferential Analysis

Inferential statistics were used to test the hypotheses. The statistical tests were selected after the data were tested for normality. The normality tests revealed that the data were not normally distributed. Hence, Spearman's correlation and the Kruskal-Wallis H test were used to analyze the data inferentially.

4.8.2.1 Spearman's Correlation

Spearman's correlation is used to measure the type and strength of an association between two variables. To analyze the data using this test, the following assumptions were considered:

- Assumption 1: The two variables tested should be continuous.
- Assumption 2: The two variables tested should represent paired observations.
- Assumption 3: A monotonic relation should exist between the two variables.

In this test, the strength of the relationship between the variables is measured using the magnitude; the direction is determined using the sign of the correlation coefficient. A correlation coefficient below 0.35 is usually considered a weak correlation, 0.36–0.67 is a moderate correlation, and above 0.67 is a strong correlation (Taylor 1990).

In this study, Spearman's correlation was used to determine the relationship between the qualifications of the awarded contractor and the contractor's performance, as measured at the end of the project. The evaluation criteria used during procurement were considered as one of the variables, and project performance was the other variable.

4.8.2.2 Kruskal-Wallis H Test

The Kruskal-Wallis H test is a nonparametric test that can be considered as an alternative to the parametric ANOVA. The Kruskal-Wallis H test is used to find statistically significant differences in the medians of two or more groups of a variable. In order to perform this test, the following assumptions were considered.

- Assumption 1: One of the dependent variables should be continuous.
- Assumption 2: One independent variable should consist of two or more categorical, independent groups.
- Assumption 3: There should be an independence of observations for the groups.
- Assumption 4: All groups' distributions of scores should have the same shape.

For this study, the Kruskal-Wallis H test was used to find the differences in the contractor group's performance in relation to the contractors' qualifications. The contractors were grouped into three equal categories based on their qualifications. For the evaluation criteria of technical proposals and past performance, each group consisted of 39–40 contractors, as shown in Table 4.7. The groups based on interview evaluation scores had 21–22 contractors (see Table 4.7).

Table 4.7: Groupings of Awarded Contractors Based on Qualification Evaluations

Evaluation criteria	Highest qualified contractors group	Moderately qualified contractors group	Lowest qualified contractors group
Technical evaluation	39	40	39
Past performance	39	40	39
Interviews	22	22	21

A similar analysis was performed regarding the projects in which a non-low bidder was awarded the contract; the purpose of the analysis was to identify the performance of the contractors who were paid the BV premium. The group divisions are shown in Table 4.8.

Table 4.8: Groupings of Non-Low-Bid Awarded Contractors Based on Qualification Evaluations

Evaluation criteria	Highest qualified contractors group	Moderately qualified contractors group	Lowest qualified contractors group
Technical evaluation	21	22	21
Past performance	21	22	21
Interviews	11	11	11

These groups were compared to identify any differences that exists between them at a 95% level of confidence (p = 0.05). To test the hypothesis statements, the median evaluation scores of the contractor groups were compared using the Kruskal-Wallis H test.

CHAPTER 5: RESULTS

5.1 Introduction

This chapter is organized into four main sections, which align with the study's research objectives and research question. The first section reports the BV premium values; the premium is a measure of the cost implications that BV procurement carries for owners. This section also contains qualifications-based characteristics of the awarded contractors. The second section identifies the project performance results of BV-procured construction projects, measured in terms of cost growth, schedule growth, and owner satisfaction with contractor performance. The third section reports on the total BV cost of the projects. This section is somewhat a culmination of the preceding sections in that the total BV cost is the sum of the BV premium and construction phase cost growth. This section also explores the sources of cost growth, with particular emphasis on non-owner-caused cost growth. The fourth section explores whether there are relationships between awarded contractors' qualifications and performance during the construction phase.

5.2 BV Premium: Cost Implications of BV Procurement

Because owners selected non-lowest bidders in the majority of the projects, it was important to quantify the magnitude of the BV premium that owners paid. The BV premium results are summarized in Table 5.1. On average, owners selected a contractor that was 7.12% more expensive than the lowest bid. The median BV premium of 0.96% was much lower than the mean, indicating the data set was somewhat skewed. This finding is logical because, by definition, the BV premium has a lower bound of 0% (when the awarded contractor is also the lowest bidder). Conversely, there is no upper bound, and the 90.93% value of the maximum BV premium identified in the data set indicates that owners are willing to select a significantly more expensive contractor in certain circumstances.

Table 5.1: BV Premium Statistics

Descriptive statistics	BV premium (%)
Mean	7.12
Median	0.96
Maximum	90.93
Minimum	0.00
Std. dev.	13.29

5.2.1 Characteristics of Awarded Contractors

The characteristics of awarded bidders were investigated through examining various aspects of the cost and qualifications proposals. First, the upfront cost implications of BV-procured D-B-B projects were investigated by identifying how often the owner selected the lowest bidder. As shown in Figure 5.1, the lowest bidder was awarded the contract in 44.9% of the projects. These results are important because it is generally perceived that BV procurement results in greater upfront costs. The study findings indicate that the lowest bidder is selected in nearly half of all cases. In the remainder of cases, the owner's evaluation team determined that a non-low bidder possessed qualifications-based advantages that justified paying a BV premium.

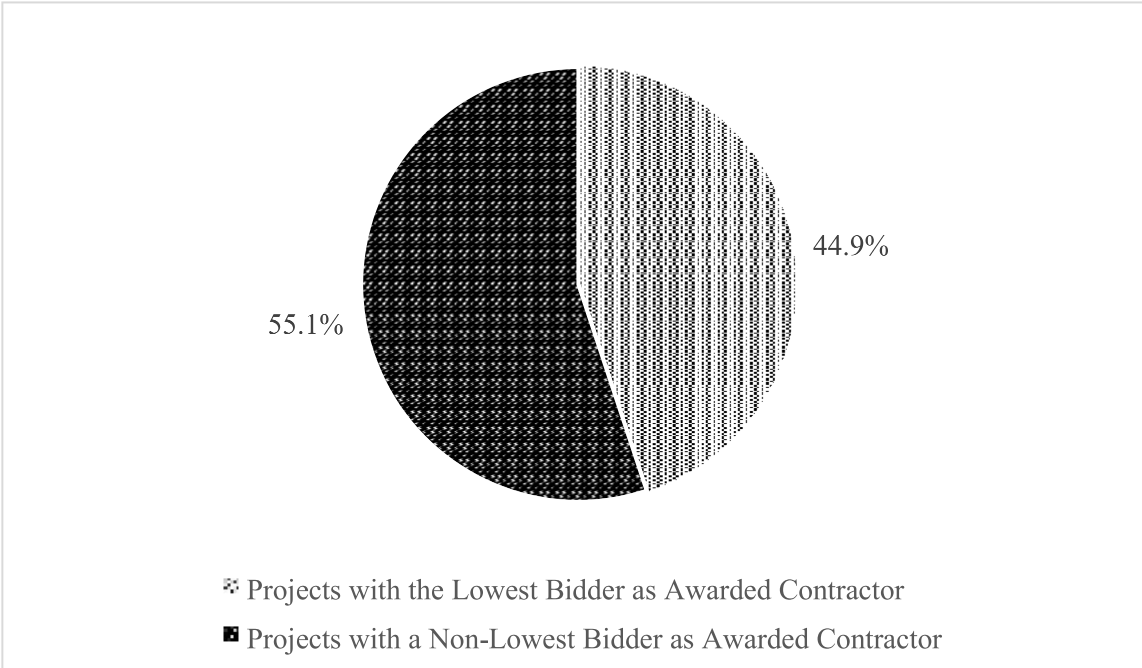

Figure 5.1: Frequency of the Lowest Bidder Being Awarded the Project

The statistical analysis shows that the owners selected the lowest bidder less often than they selected a higher bidder. The lowest bidder was awarded in 53 of the projects; in the remaining 65 projects, a non-lowest bidder was awarded the contract.

The results also indicate that owners did not always award the contract to the best-qualified contractor. A cumulative score was calculated using the evaluation scores and their respective evaluation weights in each project. The awarded contractor was the best qualified in 72.9% of the projects. It should be noted that an average of 4.3 bidders competed for each project. The qualification levels of the awarded contractors are summarized in Figure 5.2.

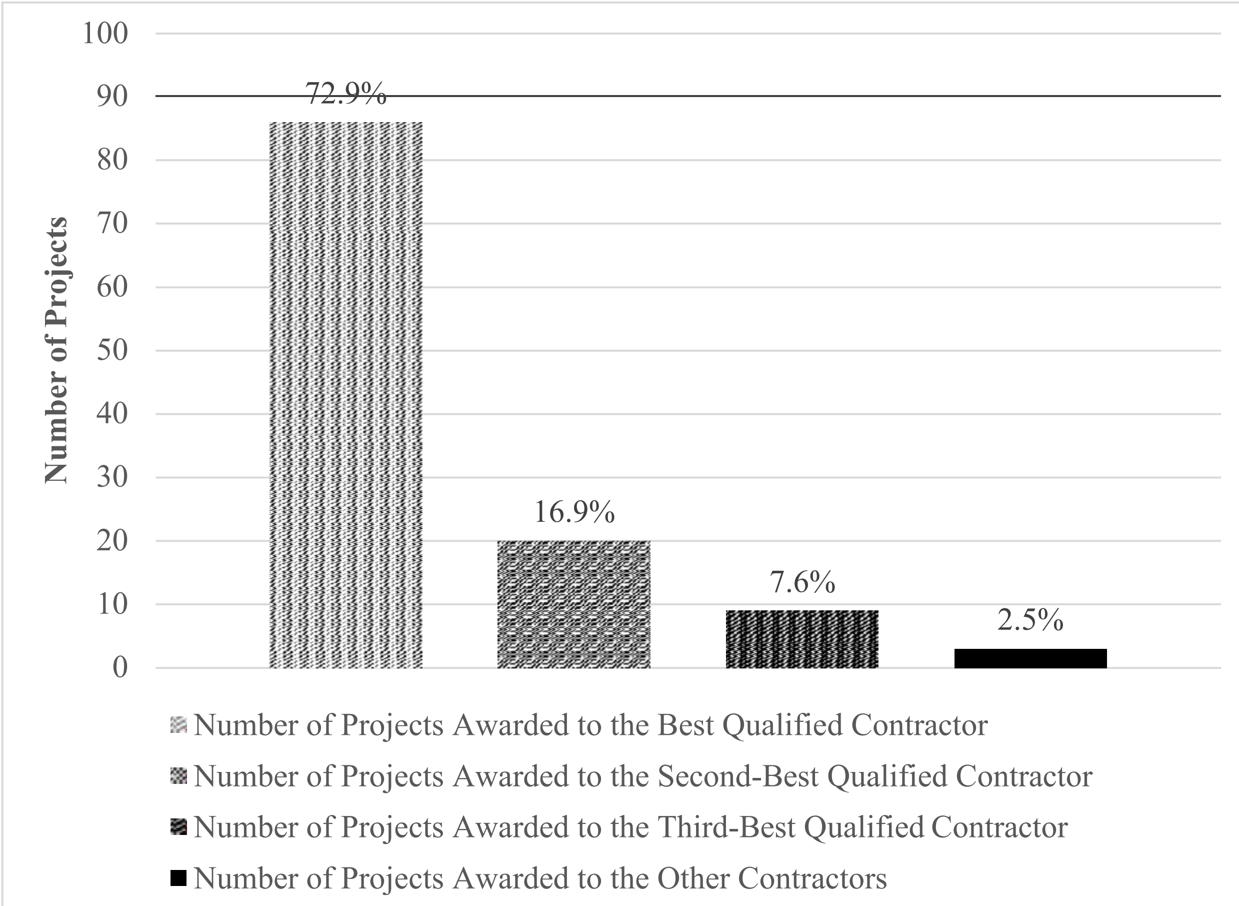

Figure 5.2: Qualification Levels of Awarded Contractors

The analysis indicates that owners typically selected contractors with bids between the lowest and average bids (see Table 5.2). The awarded bidder, on average, was 7.12% more expensive (median = 0.96%) than the lowest bidder. But compared to the average bid, the awarded bidder was 0.43% less expensive.

Table 5.2: Cost of Awarded Bid Compared to the Lowest and Average Bid per Project

	Awarded vs. lowest bid (%)	Awarded vs. average bid (%)
Mean	7.12	-0.43
Median	0.96	-0.58
Mode	0.00	0.00
Maximum	90.93	36.30
Minimum	0.00	-27.66
Std. dev.	13.29	12.00

5.3 Construction Phase Performance of BV-Procured Projects

This section reports the statistical results regarding construction-phase performance in BV-procured D-B-B projects. To answer Research Objective 2, the construction-phase performance of BV-awarded contractors was evaluated across multiple performance indicators. These performance indicators—cost growth, schedule growth, and owner satisfaction—are discussed in the subsections below.

Overall, the results show that most projects did experience cost growth and schedule growth during the construction phase. Across the data set, 88.1% of the projects experienced either cost overruns or schedule growth, as shown in **Figure 5.3**. Of those projects, 49.1% experienced both cost growth and schedule growth.

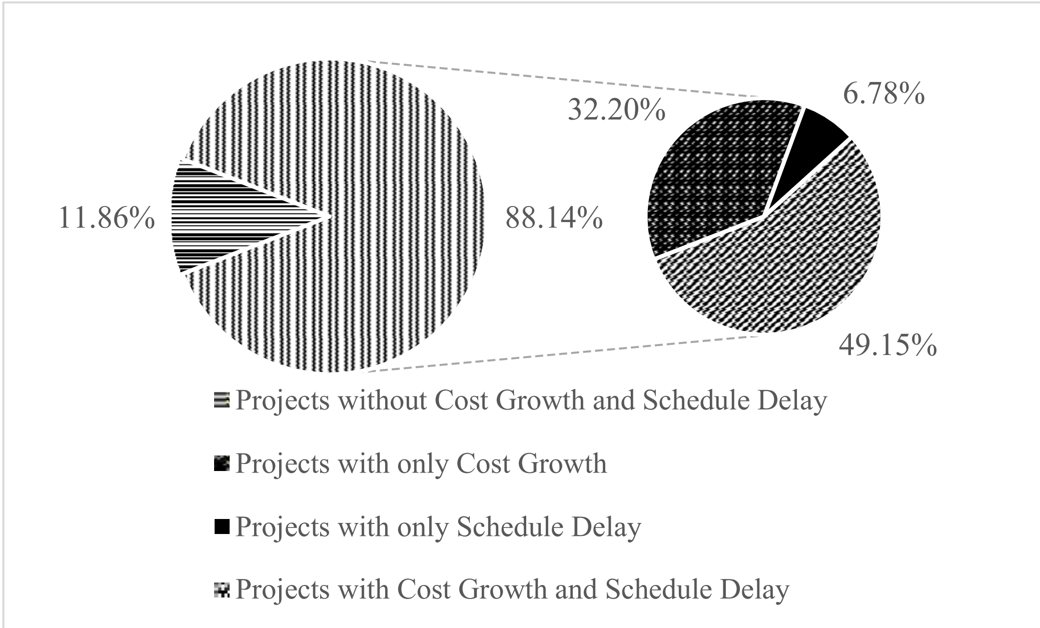

Figure 5.3: Summary of Construction Phase Cost and Schedule Performance

5.3.1 Cost Growth and Schedule Growth

The root causes of cost growth were documented in the closeout reports completed by the owners' project managers. Table 5.3 summarizes the cost growth and schedule growth experienced during the construction phase. The average cost growth was 9.69%, the median cost growth was 5.3%, and the maximum cost growth was 133.3%. The average schedule growth was 36.5%, the median schedule growth was 6.3%, and the maximum schedule growth was 317.1%.

Table 5.3: Overall Cost and Schedule Performance

	Overall cost growth (%)	Overall schedule growth (%)
Mean	9.69	36.53
Median	5.19	6.02
Mode	0.00	0.00
Maximum	133.33	317.14
Minimum	-15.52	-24.56
Std. dev.	18.98	63.67

Table 5.4 shows the significance of each root cause (owner, contractor, designer, and unforeseen) in terms of cost growth. The majority of cost growth was caused by the owner. Noncontractor cost growth accounted for virtually all cost growth: 9.67% of the 9.69% cost growth experienced (on average) in the projects.

Table 5.4: Statistics regarding Root Causes of Cost Growth

	Owner cost (%)	Contractor cost (%)	Designer cost (%)	Unforeseen cost (%)	Nonowner cost (%)	Noncontractor cost (%)
Mean	6.42	0.02	2.15	1.10	3.27	9.67
Median	0.52	0.00	0.00	0.00	0.81	5.10
Mode	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	133.33	12.04	60.93	14.48	60.93	133.33
Minimum	−15.19	−5.24	−5.35	−0.58	−5.24	−14.83
Std. dev.	18.35	1.28	7.18	2.42	7.67	19.33

Schedule growth data is shown in Table 5.5. The results reveal that the owner was the cause of the majority of schedule growth. Noncontractor-caused growth represented the vast majority of all growth: 34.61% of the total 36.53% schedule growth (on average) recorded in the projects.

Table 5.5: Statistics regarding Root Causes of Schedule Growth

	Owner growth (%)	Contractor growth (%)	Designer growth (%)	Unforeseen growth (%)	Nonowner growth (%)	Noncontractor growth (%)
Mean	25.42	1.92	5.09	4.14	11.11	34.61
Median	0.00	0.00	0.00	0.00	0.00	5.26
Mode	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	317.14	53.33	88.24	105.26	132.61	317.14
Minimum	−4.20	−24.56	0.00	−12.61	−24.56	−16.81
Std. dev.	56.00	7.81	14.56	15.01	25.18	62.80

5.3.1.1 Owners

As shown in Table 5.6, approximately 66.3% of the cost growth and 69.6% of the schedule growth were owner related. Across the projects, owner-related cost growth and schedule growth averaged 6.4% and 25.4%, respectively.

Table 5.6: Owner-Caused Cost Growth and Schedule Growth

	Owner-related factors	Other factors
Cost growth	66.29%	33.71%
Schedule growth	69.59%	30.41%

5.3.1.2 Contractors

The analysis results indicate that awarded contractors contributed minimally to project performance issues.

Table 5.4 and Table 5.5 show that the mean contractor-related cost growth and schedule growth were 0.02% and 1.92%, respectively. As shown in Table 5.7, only 0.21% of the cost growth was contractor related. Contractor-related schedule growth were more common, at 5.25%.

Table 5.7: Contractor-Caused Cost Growth and Schedule Growth

	Contractor factors	Other factors
Cost growth	0.21%	99.79%
Schedule growth	5.25%	94.75%

5.3.1.3 Designers

The results indicate that 22.16% of cost growth and 13.93% of schedule growth were due to design-related errors. The designers' effect on cost growth and schedule growth is shown in Table 5.8.

Table 5.8: Designer-Caused Cost Growth and Schedule Growth

	Designer-related factors	Other factors
Cost growth	22.16%	77.83%
Schedule growth	13.93%	86.06%

5.3.1.4 Unforeseen Conditions

Because the majority of the projects were renovations, it was important to consider unforeseen conditions that resulted in cost growth and schedule growth. Table 5.9 shows that 11.34% of the cost growth and 11.33% of the schedule growth were the result of unforeseen factors, such as concealed conditions that were uncovered when facilities were demolished during renovations.

Table 5.9: Unforeseen Conditions' in Project Performance

	Unforeseen condition-related factors	Non-unforeseen condition related factors
Cost growth	11.34%	88.66%
Schedule growth	11.33%	88.67%

5.3.2 Performance Differences between Low Bid and Non-Low-Bid Contractors

The data were statistically analyzed to compare performance in projects with a BV premium (non-lowest-bidder award) and in projects without a BV premium (lowest-bidder award). Table 5.10 shows the differences in cost growth. The average cost growth in projects with a BV premium outperformed the projects with no BV premium. The average cost growth of the projects with a BV premium was 7.6%. For the projects without a BV premium, the average was 12.2%.

Table 5.10: Cost Growth Comparison of Projects with and without BV Premium

	Owner growth (%)	Contractor growth (%)	Designer growth (%)	Unforeseen growth (%)	Non-owner growth (%)	Non-contractor growth (%)	Total cost growth (%)
			No BV Premium (n = 53)				
Mean	7.75	0.23	3.48	0.70	4.41	11.93	12.16
Median	0.47	0.00	0.32	0.00	0.88	4.77	5.27
Mode	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	133.33	12.04	60.93	7.21	60.93	133.33	133.33
Minimum	−15.19	−0.68	−5.35	0.00	−5.19	−14.83	−15.52
Std. dev.	23.11	1.66	10.21	1.52	10.53	24.55	24.54
			BV Premium (n = 65)				
Mean	5.34	−0.15	1.08	1.42	2.35	7.84	7.69
Median	0.52	0.00	0.09	0.28	1.40	5.10	5.11
Mode	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	72.87	0.76	7.82	14.48	14.48	72.87	72.87
Minimum	−0.45	−5.24	0.00	−0.58	−5.24	0.00	−5.24
Std. dev.	12.40	0.76	1.74	2.87	3.36	12.59	12.65

Table 5.11 shows similar results in terms of schedule growth. The projects with no BV premium performed better than the other projects. The average schedule growth in projects without a BV premium was 21.7%, with a median of 0.8%. For projects with a BV premium, the average and median schedule growth were 48.6% and 13.1%, respectively.

Table 5.11: Schedule Growth Comparison of Projects with and without BV Premium

	Owner growth (%)	Contractor growth (%)	Designer growth (%)	Unforeseen growth (%)	Non-owner growth (%)	Non-contractor growth (%)	Total schedule growth (%)
			No BV Premium (n = 53)				
Mean	15.62	1.44	2.71	1.97	6.12	20.30	21.74
Median	0.00	0.00	0.00	0.00	0.00	0.00	0.72
Mode	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	240.00	18.42	76.09	56.52	132.61	240.00	240.00

Minimum	0.00	−3.89	0.00	0.00	−3.89	0.00	−3.89
Std. dev.	40.25	3.97	11.15	8.35	19.44	43.86	44.28
BV Premium (n = 65)							
Mean	33.42	2.31	7.03	5.92	15.18	46.28	48.59
Median	0.00	0.00	0.00	0.00	0.00	11.30	13.07
Mode	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	317.14	53.33	88.24	105.26	106.67	317.14	317.14
Minimum	−4.20	−24.56	0.00	−12.61	−24.56	−16.81	−24.56
Std. dev.	63.93	9.73	16.37	18.21	28.00	71.80	74.08

5.3.3 Owner Satisfaction

The owners' satisfaction with contractor performance was collected upon completion of the construction phase. Out of a possible satisfaction score of 100%, owners' average satisfaction score was 95.23% (see Table 5.12).

Table 5.12: Owner's Satisfaction Scores

	Maximum	Minimum	Mean	Median	Mode	Std. dev.
Satisfaction	100%	65%	95.23%	97.5%	100%	7.37%

5.4 Total BV Cost

The cost of the BV premium was combined with construction-phase cost growth to identify the total BV cost. On average, the total BV cost was 15.14% (with a median of 8.80%) above the lowest bid with no cost growth. The full results are shown in Table 5.13.

Table 5.13: Total BV Cost Statistics

Descriptive statistic	Total BV cost (%)
Mean	15.14
Median	8.80
Maximum	133.33
Minimum	−15.52
Std. dev.	20.14

5.5 Linking Project Procurement Results with Construction-Phase Performance

The results reveal that few statistically significant correlations exist between contractor qualifications (as assessed in the procurement stage by the owner's evaluation committee) and project performance indicators. The statistically significant results of Spearman's correlation are shown in Table 5.14. Contractors' technical proposal scores and owners' satisfaction were found to have a statistically significant correlation ($r_s = -0.217$, $p = 0.018$). With a correlation coefficient of 0.189, contractors' past performance and cost growth are statistically significant ($p = 0.04$). However, the correlation coefficients are so weak that they are of little practical significance.

Table 5.14: Correlation Results between Awarded Contractor's Qualifications and Project Performance Indicators

Independent variables	Dependent variable	Correlation coefficient (r_s)	Significance (p)	# of projects
Technical proposal	Owner's satisfaction	0.240	0.028	84
Past performance	Contractor's cost growth	0.189	0.042	117
Past performance	Designer's cost growth	0.208	0.024	117
Past Performance	Owner's satisfaction	0.228	0.038	84
Interview	Contractor's schedule growth	−0.277	0.032	60
Schedule	Contractor's cost growth	0.286	0.013	75
Schedule	Owner's satisfaction	−0.281	0.033	58

5.6 Differences in Construction Phase Performance Based on Evaluation Scores of Contractor Groups

5.6.1 Group Differences in All Projects

The results of the Kruskal-Wallis H test identify the groups of contractor qualifications and project performance that have statistically significant differences. These combinations and their overall statistical significance are shown in Table 5.15. Technical proposal scores have a statistically significant difference from owner schedule growth ($p < 0.01$), total schedule impact ($p < 0.01$), and owner's satisfaction ($p = 0.02$). When past performance scores were tested in relation to designer cost growth and owner satisfaction, the pairs were found to be significant ($p = 0.04$ for designer cost growth and $p = 0.05$ for owner satisfaction). Additionally, contractor interview scores and schedule impacts have a statistically significant relationship ($p = 0.05$).

Table 5.15: Statistically Significant Combinations of Qualifications and Performance Indicators

Independent variable	Dependent variable	Overall significance (p)
Technical proposal	Owner schedule growth	<0.01
	Total schedule growth	<0.01
	Owner satisfaction	0.02
Past performance	Designer cost growth	0.04
	Owner satisfaction	0.05
Interview	Contractor schedule growth	0.05

Further, for all pairs that were identified as statistically significant, a pairwise comparison was conducted. For the pairs, the contractor groups with significant group differences are shown in Table 5.16. The contractor groups with high and moderate technical proposal scores have statistically significant differences regarding owner schedule growth at project completion. The group with high scores has a mean of 0.13 and a median of 0.0, whereas the moderately qualified group has a mean and median of 0.52 and 0.12, respectively. Groups with technical proposal scores that were moderate (owner schedule growth: mean = 0.52, median = 0.12) or low (owner schedule growth: mean = 0.13, median = 0.0) have significant group differences regarding owner schedule growth. The owners were highly satisfied with the groups with past performance scores that were higher (owner satisfaction: mean = 0.97, median = 0.91) than with groups with past performance scores that were lower (owner satisfaction: mean = 1.0, median = 0.95).

Table 5.16: Group Comparisons for All Projects

Independent variable	Dependent variable	Sig.*	Adj. sig.**	Group's qualifications	Mean	Median	Corresponding hypothesis	Hypothesis test
Technical proposal	Owner schedule growth	<0.01	0.02	High	0.1	0	H1.b	✓
				Moderate	0.52	0.12		
		<0.01	0.01	Moderate	0.52	0.12	H1.b	×
				Low	0.13	0		
	Total schedule growth	<0.01	<0.01	High	0.15	0	H1.b	✓
				Moderate	0.72	0.29		
		0.01	0.03	Moderate	0.72	0.29	H1.b	×
				Low	0.22	0.02		
	Owner satisfaction	<0.01	0.02	High	0.97	1	H1.c	✓
				Low	0.91	0.95		
Past performance	Designer cost growth	0.04	0.14	High	0.04	0	H2.a	×
				Low	0.01	0		
		0.02	0.07	Moderate	0.02	0.01	H2.a	×
				Low	0.01	0		
	Owner satisfaction	0.01	0.04	High	0.97	1	H2.c	✓
				Moderate	0.94	0.96		
Interview	Contractor schedule growth	0.02	0.06	High	–0.012	0	H3.b	✓
				Low	0.02	0		

* Significance
** Adjusted significance
✓ Statistical test supports corresponding hypothesis
× Statistical test does not support corresponding hypothesis

5.6.2 Group Differences in Projects with a BV Premium

The projects with a BV premium were analyzed to determine whether construction-phase performance differences exist based on groupings of contractor qualification scores. Table 5.17 shows the results. The pair of technical proposal score and owner schedule impact ($p = 0.01$) and the pair of technical proposal score and total schedule impact ($p = 0.01$) were found to be statistically significant. No pairs involving past performance and interview scores were found to be statistically significant.

Table 5.17: Statistically Significant Combinations of Qualifications and Performance Indicators of Contractor Groups for BV Premium Projects

Independent variable	Dependent variable	Overall significance (p)
Technical proposal	Owner's schedule impact	0.01
	Total schedule impact	0.01

Table 5.18 shows the contractor groups that have significant performance differences based on their qualification scores. The group of contractors with high technical proposal scores (total schedule growth: mean = 0.324, median = 0.054) and the group with moderate technical proposal scores (total schedule growth: mean = 0.893, median = 0.781) were found to have statistically significant group differences in total schedule impact, according to the Kruskal-Wallis H test results.

Table 5.18: Contractor Groups Comparison in Projects with BV Premium

Independent variable	Dependent variable	Sig.*	Adj. sig.**	Group's qualification	Mean	Median	Corresponding hypothesis	Hypothesis test
Technical proposal	Owner's schedule growth	0.01	0.02	Moderate	0.61	0.23	H1.b	✗
				Low	0.14	0.00		
	Total schedule growth	0.01	0.03	High	0.32	0.05	H1.b	✓
				Moderate	0.89	0.78		
		0.01	0.02	Moderate	0.89	0.78	H1.b	✗
				Low	0.25	0.11		

* Significance
** Adjusted significance
✓ Statistical test supports corresponding hypothesis
✗ Statistical test does not support corresponding hypothesis

CHAPTER 6: DISCUSSIONS AND CONCLUSIONS

6.1 Introduction

The results of this study are important for the construction industry. The findings can assist construction owners and contractors in better understanding the BV procurement method. Owners can use these results to identify the most suitable contractor for future projects. Contractors can use the findings to better understand the evaluation criteria that owners use in BV procurement. The results are further discussed in this chapter.

The study was successful in linking the project procurement phase to the project construction phase of vertical projects that were procured through the BV method and were delivered through D-B-B. This chapter summarizes the study's findings and contributions. The chapter also describes the limitations of the study, along with recommendations for further research.

6.2 Cost Implications of BV Procurement

When considering numerous projects over time, the cost implications of BV procurement compared with low-bid procurement appear to be relatively minor. The median BV premium value of 0.96% indicates that owners who use BV as a program-wide policy may typically experience minor upfront costs of selecting non-low bidders. Furthermore, the results show that the awarded contractor is less expensive than the average bidder, which indicates that owners who use BV procurement receive overall cost benefits in the market. Additionally, in nearly 45% of cases, the lowest bidder was also selected as the BV option due to their strong qualifications.

However, there are instances in which owners chose to select contractors that were substantially more expensive than the lowest bid option. Closer inspection of the project in which the BV premium value was 90.93% reveals several situational factors that might influence the owner to select a significantly more expensive contractor. First, this project had only two bidders, which means the owner's options were quite limited. Second, discussion with the owner's evaluation team revealed that the lowest-bidding contractor was unfamiliar with (and potentially unqualified to address) the hazardous material aspects of the project, which resulted in extremely low scores from the evaluation committee. Finally, the project size was relatively small, with a budget of approximately $150,000; therefore, the large percent difference between the two bidders did not correspond with a large magnitude of cost impact to the owner.

6.3 BV Project Performance

When BV-procured projects are compared with data on low-bid projects, it appears that BV projects have a more favorable cost performance during the construction phase. McKim et al. (2000) observed a cost growth of 19.9% in 25 reconstruction projects, whereas cost growth for the BV projects in the current study was 9.69%.

The BV projects can be considered to have performed exceptionally well if the owner-related causes of cost growth and schedule growth are omitted from the final project performance. Some researchers and industry experts at Design Build Institute of America argue that final project performance should not take into account the owner's scope changes (Korman, R. 2016, Slowey, K. 2016). Changes in the owner's requirements are one of the main reasons for change orders (Gunhan et al. 2007). In this study, after the owner factors were removed, the projects had a cost growth of 3.27% (see Table 5.4) and schedule growth of 11.11% (see Table 5.5). These percentages can be deemed as indicating good performance, especially for renovation projects.

Further, minimal cost growth and schedule growth were the result of contractor factors. Only 0.02% of cost growth and 1.92% of schedule growth were contractor related (see Table 5.4

and Table 5.5). Contractors were responsible for 0.21% and 5.25% of cost growth and schedule growth across all projects (see Table 5.7). These findings may indicate that BV can be an effective method for owners to use in order to achieve consistent contractor performance outcomes.

The results suggest that the contractors in BV-premium projects were more effective in managing their costs than were contractors in no-BV-premium projects. Table 5.10 shows that the 65 projects with BV premiums experienced an average cost growth of 7.69%, whereas the average cost growth was 12.16% for the 53 projects with no BV premium.

Awarded contractors in BV projects achieve strong performance in the areas of cost and schedule and receive high owner-satisfaction ratings. Of all the projects, 11.86% did not experience any cost growth or schedule growth (see Figure 5.3). According to Table 5.3, the average cost growth was 9.7% (median = 5.19%) and the average schedule growth was 36.53% (median = 6.02%). The average cost growth is much lower than the low-bid projects Pocock et al. (2000) studied. In that study, the average cost growth was 12.88% and the average schedule growth was 41.24%. Considering that 78% of the projects in the current study were renovation projects, the percentages prove that contractors accomplished their goals fairly well.

6.4 Relationship between Contractor Qualifications and Project Performance

The inferential testing identified relationships between (a) contractors receiving high qualification scores and (b) superior project performance during the construction phase. Contractor groups with better technical proposals were able to control the schedule better than were the other contractor groups and ultimately received better owner satisfaction rates (see Table 5.16). These findings support hypothesis statements H1.b and H1.c. The contractors with high qualification scores were able to achieve high performance because they identified potential risks through project-specific planning. In some previous studies, such as by Lines and Kumar (2018) and Perrenoud et al. (2017), the contractors identified risks before contracts were awarded, leading to positive results at the end of the construction phase. Because the majority of the analyzed projects in this study were renovations, it was important to identify risks beforehand in order to achieve better performance.

The contractors with high past-performance scores received better owner-satisfaction scores than did the other groups of contractors. This finding supports hypothesis statement H2.c. Owners were able to identify the contractors that had worked on projects similar to the proposed project by reviewing the contractors' past performance. A contractor that had successfully worked on a similar project was more likely to handle similar risks without affecting the overall project performance.

The results also suggest that the contractor group with better interview scores handled the project schedule better, as hypothesized in H3.b. This result was mainly due to the owner interacting with the project risk handlers, such as the project manager, site superintendent, and critical subcontractors before awarding the project. During this process, the owner identified the contractor most suitable for the project and, therefore, achieved better schedule performance.

6.5 Summary of Findings

The findings of this study can be summarized as follows:

- Construction owners can potentially save money through using BV procurement rather than the low-bid method.
- Projects with a BV premium have better cost performance than do projects without a BV premium.

- Contractors with better technical proposals, past performance, and interview scores tend to achieve superior performance during the construction phase.

6.6 Contributions

The study makes several contributions to the existing body of knowledge. First, this study proposed a new metric—the BV premium—to quantify the cost implications of BV procurement relative to the low-bid method. This study also developed the concept of a total BV cost metric to determine the exact cost burden of the BV procurement method for owners. The BV premium and the BV cost metric are important because, even though previous studies have demonstrated that BV procurement results in superior construction-phase performance, owners should not ignore the BV premium that is paid to achieve the superior results. Finally, this study is the first to establish potential linkages between procurement-phase evaluations and the construction-phase performance of the awarded contractor. The findings further justify the conclusion that qualifications are a legitimate factor to consider during contractor procurement.

6.7 Limitations and Recommendations for Future Research

A limitation of the study is that it was confined to project in the United States and Canada. Because the performance of a project is affected by the geographic location, the findings of this study may not be useful to owners and contractors outside of the United States and Canada. Another limitation is that owner satisfaction scores were available for only 84 of the 118 projects. Further, this study did not consider differences between the monetary size of the projects. Other limitations may include the fact that the study is confined to D-B-B delivered vertical projects.

Future research could consist of performing the same analysis on horizontal projects, such as roads and bridges. The researchers could try to link the project-procurement phase to the performance phase.

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APPENDIX A—SAMPLE PROJECT EVALUATION MATRIX

#	Criteria	Detailed weight	Vendor 1	Vendor 2	Vendor 3
1	Lump sum	30	$839,000	$854,000	$792,200
2	Project capability	10	6.3	7.5	2
3	Risk assessment	15	6.3	10	2
4	Value added	10	5	7.5	3.3
5	Interview—project manager	15	8.8	0	3
6	Interview—site superintendent	15	6.3	5	5
	Firm PPI				
7	Ability to manage cost	0.17	9.67	10	10
8	Ability to maintain schedules and respond to request in a timely manner	0.17	10	10	10
9	Quality of work	0.17	9.67	10	10
10	Professionalism and ability	0.17	10	10	10
11	Ability to meet client expectations and respond to address user complaints and/or unique requirements	0.17	10	10	10
12	Ability to identify, communicate, and mitigate risk	0.17	10	10	10
13	Ability to follow client rules, regulations, and requirements	0.17	10	10	10
14	Overall customer satisfaction and willingness to hire firm again	0.17	10	10	10
15	Number of different projects	0.17	3	3	3
16	Number of different clients	0.17	3	2	3
	Project manager PPI				
17	Ability to manage cost	0.17	9.33	0	9.67
18	Ability to maintain schedules and respond to request in a timely manner	0.17	9.67	0	9.67

20	Professionalism and ability	0.17	9.33	0	10
21	Ability to meet client expectations and respond to address user complaints and/or unique requirements	0.17	9	0	10
22	Ability to identify, communicate, and mitigate risk	0.17	9	0	9.67
23	Ability to follow client rules, regulations, and requirements	0.17	9.67	0	10
24	Overall customer satisfaction and willingness to hire firm again	0.17	9.33	0	10
25	Number of different projects	0.17	3	0	3
26	Number of different clients	0.17	3	0	3
	Site superintendent PPI				
27	Ability to manage cost	0.17	9.33	8.5	9
28	Ability to maintain schedules and respond to request in a timely manner	0.17	9.67	8.5	9.33
29	Quality of work	0.17	9.67	8.5	9
30	Professionalism and ability	0.17	9.67	8.5	9
31	Ability to meet client expectations and respond to address user complaints and/or unique requirements	0.17	9.33	9	9.33
32	Ability to identify, communicate, and mitigate risk	0.17	10	8	9
33	Ability to follow Client rules, regulations, and requirements	0.17	10	8.5	9.33
34	Overall customer satisfaction and willingness to hire firm again	0.17	10	8.5	9.33
35	Number of different projects	0.17	3	2	3
36	Number of different clients	0.17	3	2	2

APPENDIX B—SAMPLE FINAL WEEKLY RISK REPORT

Dalhousie University

Final Weekly Risk Report

May 12, 2011

Project ID:	2015-025		
Project Name:	Washroom Renovations, New Eddy Shirreff Hall	Percent Complete:	100%
Client PM:	Stuart McCormack	Overall Client PM Satisfaction:	-
Vendor:	RCS Construction	# Unresolved Risks:	0
Vendor PM:	Nick Tingley	# Impacts to University Primary Functions:	0

Cost analysis		Schedule analysis	
Awarded cost	$839,000	Notice to proceed date	4/7/2015
Total cost impacts	$ 42,825	Original completion date	7/31/2015
Current project cost	$881,825	Awarded project duration	116
Percent cost impact	5.1%	Total schedule impacts	57
		Forecasted completion date	09/26/15
		Percent delayed	49.1%
Client change order rate	+0.2%	Client schedule impacts	+0.0%
Contractor change order rate	+0.0%	Contractor schedule impacts	+4.3%
Design change order rate	+2.0%	Design schedule impacts	+30.2%
Unforeseen change order rate	+2.9%	Unforeseen schedule impacts	+14.7%
Noncontractor CO rate	5.1%	Noncontractor delay rate:	+44.8%

Schedule analysis	Number of risks	Cost impacts	Schedule impacts
Overall client impacts	4	$1,460	0
Client: Scope change	3	$(188)	0
Client: Contract/payment	0	—	0
Client: Regulatory/codes/permits	1	$1,648	0
Client: Other	0	$ -	0
Overall contractor impacts	3	$ -	5
Contractor: Error/omission/general issues	0	$ -	0
Contractor: Sub/supplier issue	3	$ -	5
Contractor: Innovation/efficiency	0	$ -	0
Overall design impacts	9	$16,996	35
Design: Error/omission in design	9	$16,996	35
Overall unforeseen impacts	6	$24,369	17
Unforeseen: Existing conditions	6	$24,369	17
Unforeseen: Unforeseen events/weather	0	—	0
	22	$42,825	57

APPENDIX C—SAMPLE OWNER SATISFACTION SURVEY

TO BE COMPLETED BY THE CLIENT PROJECT MANAGER UPON PROJECT COMPLETION

Please rate each of the criteria on a scale of 1 to 10 to the best of your knowledge, with 10 representing that you were very satisfied (and would hire the firm/individual again) and 1 representing that you were very unsatisfied (and would never hire the firm/individual again). If you do not have sufficient knowledge of past performance in a particular area, please leave it blank.

This Close Out Survey pertains to the Firm & Individuals listed below:

Firm:
Individuals:

#	Criteria	Unit	Score
1	Ability to manage costs	(1–10)	
2	Ability to maintain schedules and respond to requests in a timely manner	(1–10)	
3	Quality of work	(1–10)	
4	Professionalism and ability to manage	(1–10)	
5	Ability to meet client expectations and respond to/address user complaints and/or unique requirements	(1–10)	
6	Ability to identify, communicate, and mitigate risk	(1–10)	
7	Ability to follow Client rules, regulations, and requirements	(1–10)	
8	Overall customer satisfaction and willingness to hire firm again	(1–10)	

Overall Average Close Out Rating: _

APPENDIX D—KRUSKAL-WALLIS *H* TEST RESULTS

Independent variable	Dependent variable	Significance
Technical proposal	Owner’s cost impacts	0.151
	Contractor’s cost impacts	0.554
	Designer’s cost impacts	0.404
	Other cost impacts	0.860
	Total cost impacts	0.183
	Owner’s schedule impacts	0.004
	Contractor’s schedule impacts	0.584
	Designer’s schedule impacts	0.496
	Other schedule impacts	0.288
	Total schedule impacts	0.003
	Overall satisfaction of the owner	0.118
Past performance	Owner’s cost impacts	0.998
	Contractor’s cost impacts	0.148
	Designer’s cost impacts	0.048
	Other cost impacts	0.528
	Total cost impacts	0.490
	Owner’s schedule impacts	0.066
	Contractor’s schedule impacts	0.275
	Designer’s schedule impacts	0.251
	Other schedule impacts	0.179
	Total schedule impacts	0.131
	Overall satisfaction of the owner	0.050
Interview	Owner’s cost impacts	0.076
	Contractor’s cost impacts	0.293
	Designer’s cost impacts	0.932
	Other cost impacts	0.330
	Total cost impacts	0.647
	Owner’s schedule impacts	0.632
	Contractor’s schedule impacts	0.049
	Designer’s schedule impacts	0.135
	Other schedule impacts	0.699
	Total schedule impacts	0.676
	Overall satisfaction of the owner	0.079